Space Technology Research Grants

Automated Robust Maneuver Design and Optimization

Completed Technology Project (2015 - 2019)

Project Introduction

NASA is seeking improvements to the current technologies related to Position, Navigation and Timing. In particular, it is desired to automate precise maneuver planning and optimization and gradually implement the technologies with increasing levels of autonomy. Typically, maneuvers are designed on the ground and uploaded to operating spacecraft (SC) when a communication channel is open. This works well with avoidance maneuvers regarding SC in Earth orbit or trajectory correction maneuvers in deep space with a generous link budget. In justification for automation, quick decisions may need to be made when a communication channel is not available or precious time in a link budget will be used for maneuver planning instead of scientific pursuit. To compound issues, the optimality of a non-robust maneuver for a particular scenario may break down in the presence of uncertainty, which possibly reduces SC lifetime or increases risk. For these reasons, it is important to achieve automated, robust maneuver design with optimization. Design optimizations that do not include stochastic processes are not desensitized to random perturbations in the state or other parameters and therefore are not suitable for robust autonomous applications. On the other hand, comprehensive processes such as MC are computationally intractable for on-board use. Without information such as mean values, standard deviations or probability of failure, the reliability of an optimization may not be known. Because astrodynamic systems and flight hardware contain many uncertainties, any autonomous optimization must take uncertainty into account. It is proposed that, by building on the work of Polynomial Chaos (PC), utilizing separated representations (SR) to estimate the state and maneuver of a SC will allow autonomous planning and optimization. Similar to PC, SR uses a polynomial surrogate model to produce an accurate PDF of a state without Gaussian assumptions and with a fast convergence time. The difference is that the theoretical computation costs of SR are lower than that of PC. Whereas PC computation costs increase exponentially with respect to stochastic dimension, SR costs increase only quadratically. It has been shown that polynomial surrogates are computationally efficient for optimization when compared to traditional techniques and it has also been shown that polynomial surrogates benefit greatly from multi-core processing. These increases in efficiency, along with decreasing costs relative to PC, are hypothesized to enable autonomous, on-board optimization and planning, which is a current target in NASA's technology road-map. A systematic analysis of increasing dimensions for varying ODEs will be enforced in order to determine the computation times of SR. Afterward, the goal is to estimate a maneuver PDF with SR. The approach will involve adding three more stochastic dimensions of delta velocity to the input dimensions in order to replicate a maneuver. Instantaneous or continuous burns will be investigated using this method. The second phase of research will involve implementing an optimization routine within the developed SR framework. Robust optimization has also been accomplished with other polynomial surrogates such as PC, as well as traditional methods such as MC. Therefore, there are baselines of performance

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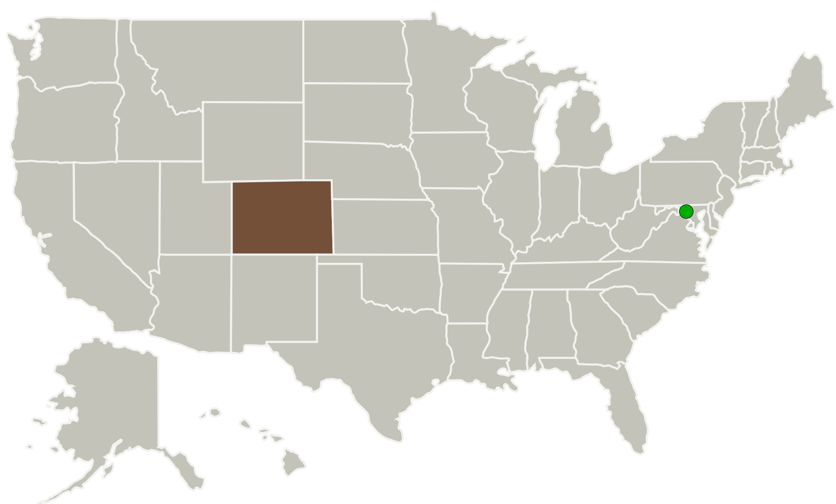
to compare to. It is a high priority to compare the performance of SR with these other methods. The last significant portion of research will deal with implementation. Specifically, the performance of SR on relevant multi-core processors will be compared to that of existing benchmarks. After initial multi-core implementation, work at NASA centers will help narrow the field of possibilities and allow for the programming of SR with available flight hardware in mind. The performance of maneuver planning and optimization for these systems will be studied and maximized for potential future use in NASA missions.

Anticipated Benefits

Consistent with NASA's desire to improve upon current technologies related to Position, Navigation and Timing, this project aims to advance autonomous optimization of in-space manuevers by taking into account uncertainties in astrodynamic systems and flight hardware.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
University of Colorado Boulder	Lead Organization	Academia	Boulder, Colorado
Goddard Space Flight Center(GSFC)	Supporting Organization	NASA Center	Greenbelt, Maryland

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

University of Colorado Boulder

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Brandon M Jones

Co-Investigator:

Marc Balducci

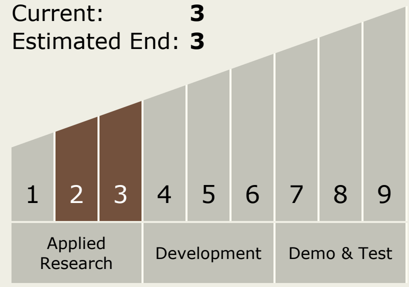
Primary U.S. Work Locations
Colorado

Project Website:

https://www.nasa.gov/strg#.VQb6T0jJzyE

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Technology Areas

Primary:

- TX05 Communications, Navigation, and Orbital Debris Tracking and Characterization Systems
  └ TX05.1 Optical Communications
    └ TX05.1.1 Detector Development

Target Destination

Earth